BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Scientific Considerations of an Early, Decoupled ATM Mission at an Inclination of 50° - Case 630

DATE: June 5, 1968

FROM: D. B. Wood

ABSTRACT

Solar activity from 1970 to 1972 and the duration of solar flares have been examined to evaluate the merits of an early, decoupled, 50° inclination ATM mission lasting 28 days or less. It is shown that

1. Solar activity decreases by a factor of about two between late 1970 and early 1972.

2. The probability of observing a solar flare during the few days of 100% viewing time available at 50° inclination is probably less than 0.5.

3. In a 50° orbit the White Light Coronograph experiment may be seriously degraded for at least one week during the time chosen for "optimum" viewing, since the sun then remains very close to the earth's horizon.

4. The most active part of a solar flare occurs in a time short compared to the 56-minute sunlit time available on a normal 250 n.m. orbit of low inclination.

5. Since activity changes are small for this period, the most important factor in successful flare observations from the ATM is total integrated viewing time. For 28 days at 50° inclination the increase in time is about 10% over 28.5°. The only way to increase viewing time significantly is to increase mission duration or go to inclinations near 66.5°. For a given inclination, a 56-day mission in early 1972 is comparable, scientifically, to a 28-day mission in late 1970.

(NASA-CR-95472) SCIENTIFIC CONSIDERATIONS OF AN EARLY, DECOUPLED ATM MISSION AT AN INCLINATION OF 50 DEG (Bellcomm, Inc.) 14 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

This memo discusses the possible impact on the Solar ATM scientific experiments of an early, decoupled launch at 50° inclination* as compared with the baseline S-IV-B workshop multi-discipline facility. The merits of an orbit with inclination higher than 50° are mentioned here only briefly and will be discussed in a later memorandum. The scientific aspects addressed are

A. the importance of solar flare activity to the five ATM experiments,

B. the observational characteristics of solar flares, and

C. the probability of observation of a solar flare.

Finally the interplay with mission parameters is discussed and the results summarized.

II. THE IMPORTANCE OF SOLAR ACTIVITY TO THE ATM EXPERIMENTS

A. The AS&E Imaging X-ray Telescope[1] (S-054) experiment was originally oriented primarily toward flare observations, and hence depended greatly on flares for scientific return. It is our understanding that this experiment has been redirected to depend less upon flares.

B. The GSFC Dual X-ray Telescope[2] (S-056) experiment depends upon the sun being active. Flare observations are important, but there will be a good scientific return even with no flare observations. This experiment would benefit greatly if the mission duration were in excess of one solar rotation (about 27 days).

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*50° inclination was considered here as the maximum achievable without yaw steering on launch from Cape Kennedy.

C. The two UV experiments (S-055, Harvard;[3] S-053, NRL[4]) are geared toward flare observations in the instrument design, but much good scientific return is guaranteed even without high solar activity.

D. The White Light Coronograph[5] (S-052) experiment will be of high scientific value during any part of the solar cycle. Flare activity would be a scientific bonus. It also should be pointed out in reference to the later discussion that this experiment depends on seeing the solar corona out to six solar radii (i.e. to 1.5° from the sun's limb).

In summary, all the experiments would profit greatly from flare activity, but would yield good scientific results even without flares. The individual principal investigators are being queried regarding their evaluation of the importance of flare activity to their experiments. Their input is very important to this matter.

III. OBSERVATIONAL CHARACTERISTICS OF SOLAR FLARES

A. Figure 1 shows, schematically, a solar flare.[6] Flares show such a wide dispersion of properties that it is difficult to describe a "typical" flare.

B. Total duration of flares, by class, are summarized in Table I.[7,8] The tabular entries are

1. the mean value based on the IGY 1957 maximum,
2. the mode value for the same maximum,
3. a mean value extracted from various pre-IGY sources, and
4. observed ranges in duration.

C. Rise time of flares, by class,[7,8] is likewise summarized in Table I. The rise and peaking of a flare is the time when all the exciting physical processes are taking place. The exponential-like decay back to the "steady state" is interesting, but not as crucial to the understanding of the flare process.

D. To summarize this section, notice that the total duration of a flare is roughly comparable to the sunlit time in commonly used orbits of 250 to 300 n.m. at low inclination - about 56 minutes. It is thus possible, but unlikely, to observe one flare in its entirety from such orbits. On the other hand, the physically most important portion of a flare, the rise, is relatively short compared to 56 minutes. It is thus highly likely that the entire rise of a flare can be seen from a typical low earth orbit. If a flare occurs at all during this 56-minute period then there is a 0.60 probability of observing all of its rise (assuming 14-minute rise time). Thus if the probability of observation (see below) is .5, the probability of seeing the entire rise is .3.

IV. PROBABILITY OF OBSERVATION OF A SOLAR FLARE

A. The question is conveniently broken into the question of

1. the probability of a flare occurring anywhere on the sun per unit time,
2. the probability of observing one or more flares with 100% observing time, and
3. the probability of observing one or more flares in an orbit subject to solar occultation by the earth.

B. The probability of one or more flares occurring anywhere on the sun is dependent upon the Zurich (or Wolf) sunspot number - an extrapolated count of the total number of spots on the entire solar surface on a given day. The expected number of flares per day (of Class 1 or greater) is 1/25 of the sunspot number;[9] however, the spread is about $\pm$70%. Of these flares about 19-25% are Class 2, and 1-3% Class 3.[8] The sunspot number is correlated with the solar cycle. The mean maximum is 103 spots, but the range of maxima is from 49 to 193.[10] Figure 2 shows the flare rate predicted for this solar cycle, including the $\pm 2\sigma$ variations in the predicted sunspot number. The $\mp$70% spread in the correlation between flare activity and sunspot number would broaden the range of possible variation even more. Notice that the drop in predicted activity from late 1970 to early 1972 is about a factor of two.

The current evidence is that flares occur randomly in time, although spatially they are normally associated with large sunspot groups. Figure 3 shows flare probabilities, based on the Poisson formula, for a given time interval and various possible flare rates. The lower curve (0.2 flare in 2-1/2 days) is an optimistic estimate for Class 3 flares in 1971. The other three solid curves represent possible values for Class 2 flares. The dashed curve represents a reasonable value for Class 1 flares (8 in 2-1/2 days). This figure has three time scales. The lower scale, along with the "Probability of Occurrence" scale, gives the probability of occurrence of one or more flares on the entire sun in the specified time interval, for the flare rates shown.

C. The probability of observing one or more flares under 100% observing time is shown by the "Total Observing Time" and "Probability of Detection" scales. The necessary time interval to arrive at a given probability level is doubled, since only half of the sun is visible at one time.

D. The probability of observing one or more flares in an orbit subject to solar occultation by the earth 40% of the time (typical for 250 n.m. orbit) is shown by the "Actual Mission Days" and "Probability of Detection" scales. We see that in fourteen mission days we have about an 80% chance of one or more Class 2 flares in early '72. Unless the mission is at least 56 days, there is little chance of seeing a Class 3 flare. In this part of the IGY maximum (3-4 years past maximum), which was more active than the present one, Class 3 flares occurred at a rate of about 11 per year.[12] There is evidence that Class 3 flares may not occur at all below a certain level of solar activity.

E. To consider the probability of observing one or more flares during the unocculted viewing period of one or more days, such as could be achieved by a 50° inclination orbit, we return to the "Total Observing Time" scale. In one day of unocculted observing the probability of seeing one or more flares is on the order of 0.1 to 0.25. This is a very sensitive portion of the probability curve, so an increase to four unocculted days raises the probability to values between 0.55 to 0.90. Recall from Figure 2 that the most likely flare rate in early 1972 is near 1 per 2 1/2 days, so that the applicable probabilities above are the lower values, namely 0.1 in one day and 0.55 in four days. At the end of 1970, the applicable probabilities are 0.25 in one day and 0.8 in four days. If the inclination were higher, near 65°, the 100% observing period would be long enough to yield a reasonable probability of flare observation.

V. INTERPLAY WITH MISSION PARAMETERS

A. High Versus Low Inclination

By orienting the pole of the ATM orbit in the general direction of the sun near the summer or winter solstice, when the sun is at its maximum distance above or below the equator (23.5°), sunlit time in the orbit can be increased. For an orbital inclination near 66.5° (90-23.5°), the sunlit time is 100% for many days, as the orbit gradually precesses. Within about $\pm 17°$ of 66.5°, there is 100% sunlit time for a few days. We consider here the merit of a 50° inclination orbit which is just in the regime where there is some unocculted 100% sunlit time.

1. In a 50° orbit, the additional unocculted viewing time is of marginal scientific gain for flare observations for the following reasons.

   (a) The 100% unocculted viewing time is so short (a few days) that the probability of viewing a flare in this time is low. However, we are dealing with steep slopes on the probability curve, and a small variation in the unocculted period or in predicted flare rate can significantly alter the probabilities.

   (b) The physically most interesting portion of a flare occurs in a time interval short compared to a nominal 56-minute sunlit time.

2. In a 50° orbit, tailored to yield a maximum interval of unocculted viewing, the sun is very close to the earth's horizon during the unocculted period, obscuring about half of the corona. The sun is never more than 7° from the earth's horizon for five days on either side of the unocculted period, and essentially skims the earth's horizon during the unocculted period. Thus the coronograph experiment would be degraded, and maybe even inoperable, for at least one week during the very time chosen for "optimum" solar viewing. If the inclination were higher, i.e., more than about 55-60°, the sun would no longer remain too close to the earth's horizon.

B. "Early" Versus "Late" Mission (4Q '70 to 1Q '71 Versus 4Q '71 to 1Q '72

The predicted rate of decrease of flare activity during this interval is about a factor of two. In a 14-day mission, this reduces the probability of observing one or more Class 2 flares from about 0.95 to 0.8. Since the statistics on Class 3 flares are so uncertain, it is difficult to assess the impact on the probability of observation. During the same portion of the IGY, Class 3 flare occurrence only dropped from 12 per year to 10 per year.[12]

C. Long Versus Short Mission

Obviously the longer the mission the greater is the probability of flare observation. More exactly, we seek the product of long integrated sunlit time times solar activity. Solar viewing time increases directly as mission duration, but only slightly with inclination. If an "early" mission provides total sun viewing time of 1/2 that of a "late" mission, then the two missions are roughly comparable scientifically, since the sun is about twice as active in late 1970 as in early 1972.

VI. SUMMARY

A. It is scientifically highly desirable to observe solar flares of Class 2 or greater on the ATM mission, but it is not absolutely necessary.

B. There is questionable scientific gain in an orbit inclined at 50° over an orbit inclined near 28.5°. Of special note is

1. the probability of flare occurrence in a couple of unocculted days is very sensitive to the flare rate and the exact unocculted period. The range in probabilities may be from 0.1 to 0.9,
2. the White Light Coronograph experiment is degraded for at least one week of the 50° mission, and
3. for inclinations higher than 50° the mission becomes more attractive.

C. In the time period from late 1970 to early 1972, predicted solar activity falls off by a factor of two. The important factor is flare rate times mission duration, so lengthening the mission could compensate for decreased activity.

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D. B. Wood

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Attachments
References
Table I
Figures 1-3

REFERENCES

1. Giacconi, R., 1966, "X-ray Spectrographic Telescope", Experiment Proposal from American Science and Engineering Co.

2. Milligan, J., 1966, "Dual X-Ray Telescopes", Experiment Proposal from Goddard Space Flight Center.

3. Goldberg, L., 1966, "UV Spectrometers", Experiment Proposal from Harvard College Observatory.

4. Purcell, J. D., 1966, "UV Coronal Spectrographs", Experiment Proposal from Naval Research Laboratory, (1966).

5. Newkirk, G., 1966, "White Light Coronograph", Experiment Proposal from High Altitude Observatory.

6. From several papers presented at the Solar Astronomy meeting of the American Astronomical Society (February 1968).

7. Smith, H. J. and Smith, E.V.P., 1963, Solar Flares, (Macmillan, New York).

8. deJager, C., 1959, "Structure and Dynamics of the Solar Atmosphere", in Handbuch der Physik, Vol. 52 (Springer Verlag, Berlin).

9. Brandt, J. C. and Hodge, P. W., 1964, Solar System Astrophysics, (McGraw Hill).

10. Allen, C. W., 1965, Astrophysical Quantities, (Athlone Press, London).

11. Benson, R. H., Fleishmann, E. F., and Hill, R. J., 1968, "Earth Orbital Lifetime and Satellite Decay", Astronautics and Aeronautics, 6, 38.

12. deGaston, A. N., 1966, "Variation of Interplanetary Solar Cosmic Ray Radiation Hazard with Solar Cycle", Bellcomm Memorandum for File, (October 25, 1966).

TABLE 1

FLARE LIFETIMES AND RISE TIMES

	CLASS	MEAN (BASED ON IGY)	MODE (BASED ON IGY)	"TEXTBOOK" MEAN	RANGE
	1	32 MIN.	12 MIN.	20 MIN.	4-43 MIN.
LIFETIME	2	69 MIN.	62 MIN.	35 MIN.	10-90 MIN.
	3	146 MIN.	62 MIN.	1 HOUR	50 MIN.-7 HR.
	1	10 MIN.	5 MIN.	5 MIN.	1-15 MIN.
RISE TIME	2	16 MIN.	4 MIN.	8 MIN.	1-15 MIN.
	3	----	----	15 MIN.	5-30 MIN.

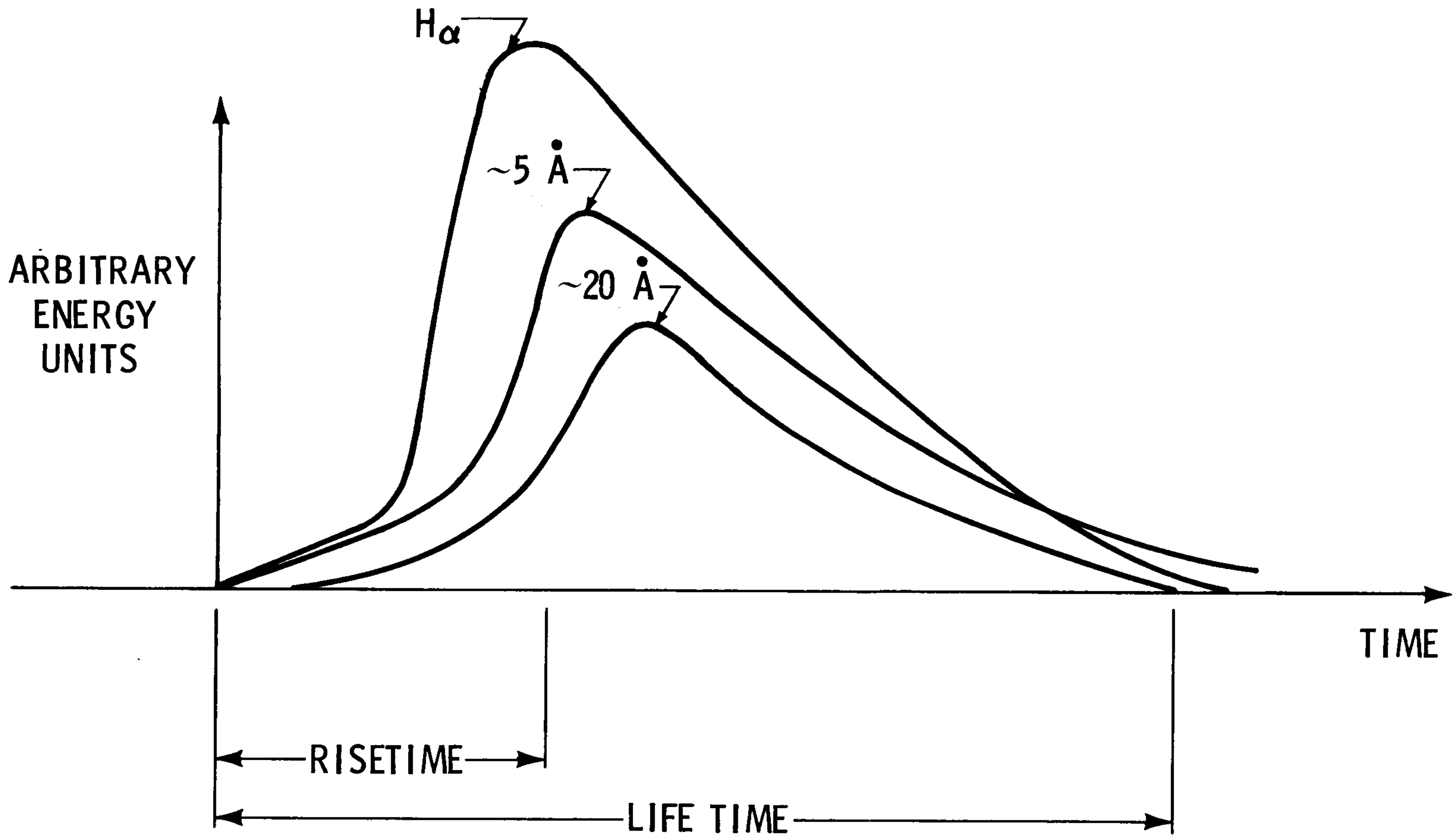

FIGURE 1 - TYPICAL SOLAR FLARE, SHOWING WAVELENGTH DEPENDENCE OF TIME OF MAXIMUM

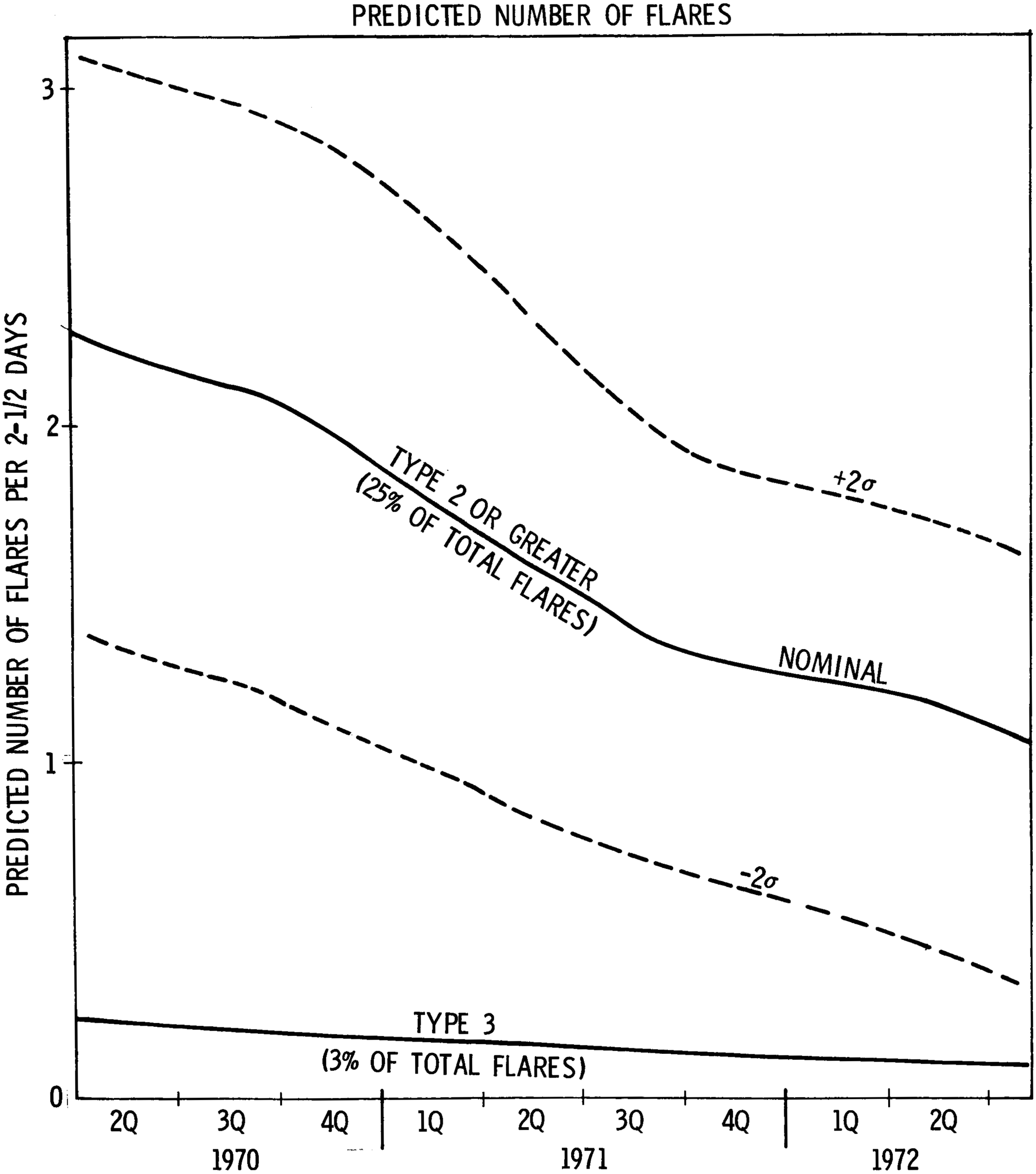

FIGURE 2 - FLARE RATE FOR 1970-1972, BASED ON PREDICTED SUNSPOT NUMBER

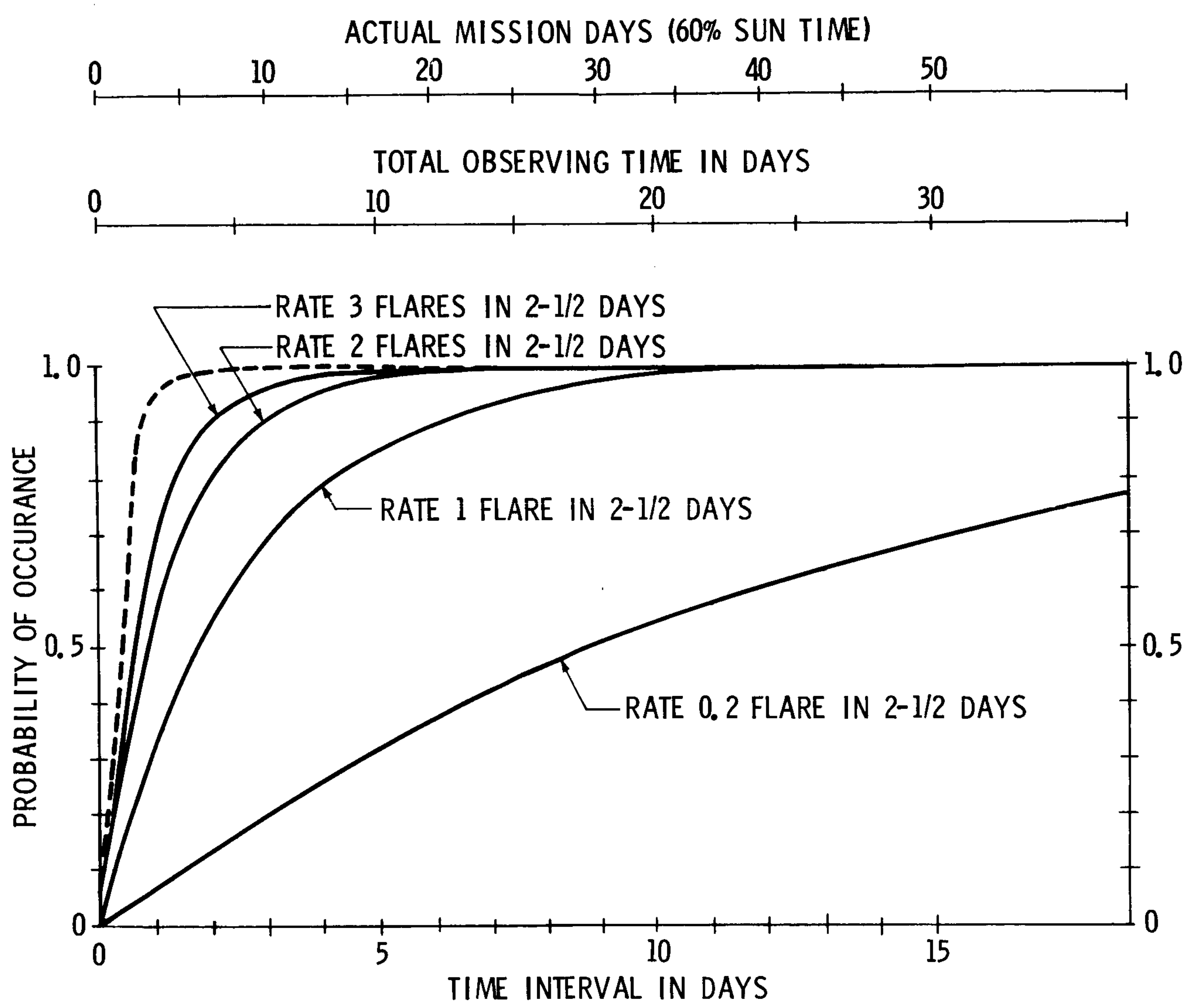

FIGURE 3 - FLARE PROBABILITY FOR VARIOUS FLARE RATES

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